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May 10-12
2010

Small x physics with ALICE

Tapan Nayak for the ALICE Collaboration

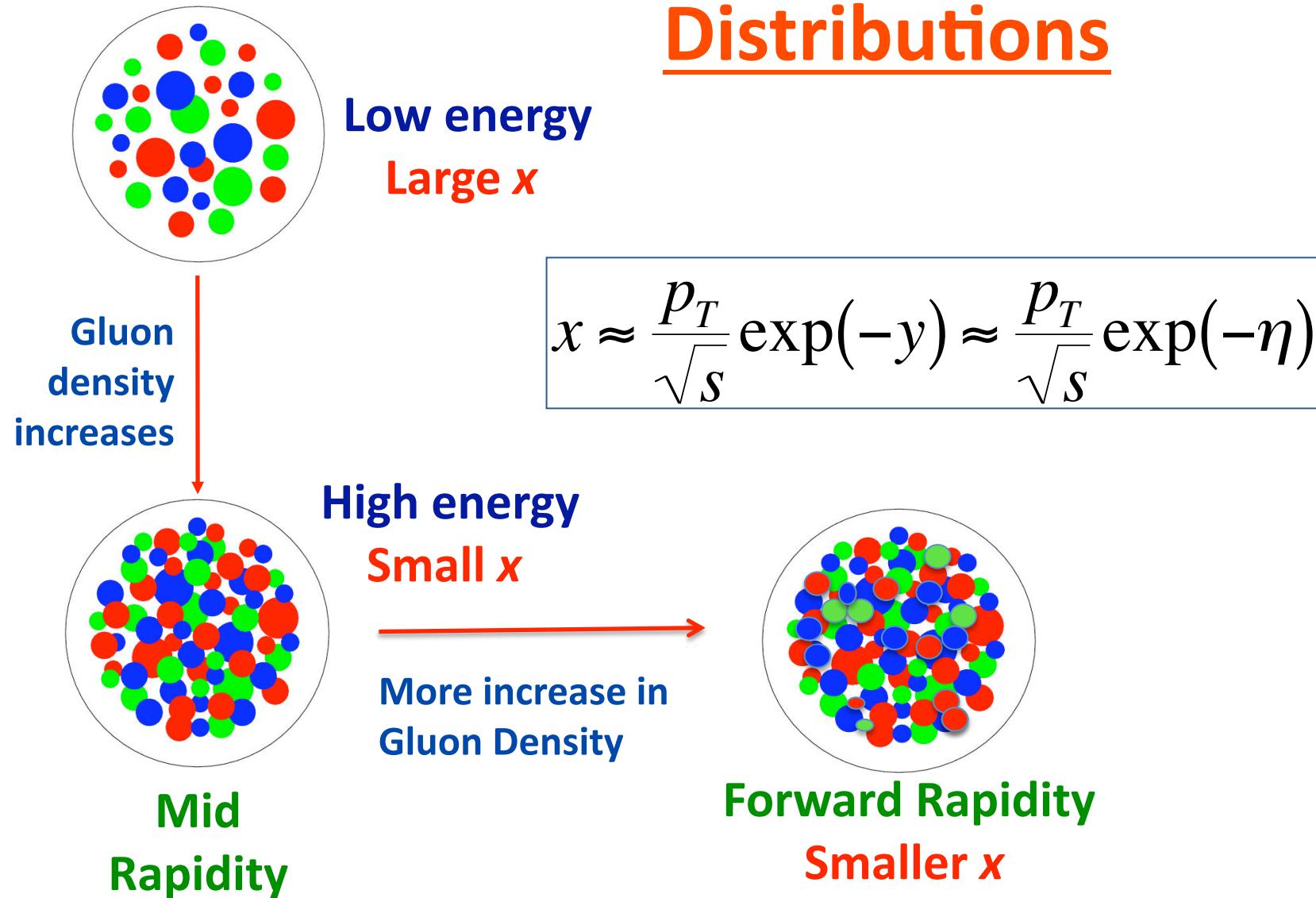


Small x physics with ALICE

OUTLINE:

1. Introduction
2. ALICE: present Capabilities
3. ALICE Future plans: Forward EM Calorimeter
4. Sample of Results from ALICE p-p runs so far

Study of Small- x Parton Distributions





Collisions at the LHC

- **p-p collisions**
 - Test of pQCD and saturation models in a new \sqrt{s} and x regime
 - Baseline for Pb-Pb
- **p-Pb collisions**
 - Probe nuclear PDFs
 - Disentangle initial and final state effects
- **Pb-Pb collisions**
 - Probe the hot and dense medium

p-p: $\sqrt{s} = 14 \text{ TeV}$
p-Pb: $\sqrt{s} = 8.8 \text{ TeV}$
Pb-Pb: $\sqrt{s}_{\text{NN}} = 5.5 \text{ TeV}$

- Unexplored small- x region
 - Window on the rich phenomenology of high-density PDFs:
Shadowing, Gluon saturation, Color Glass Condensate

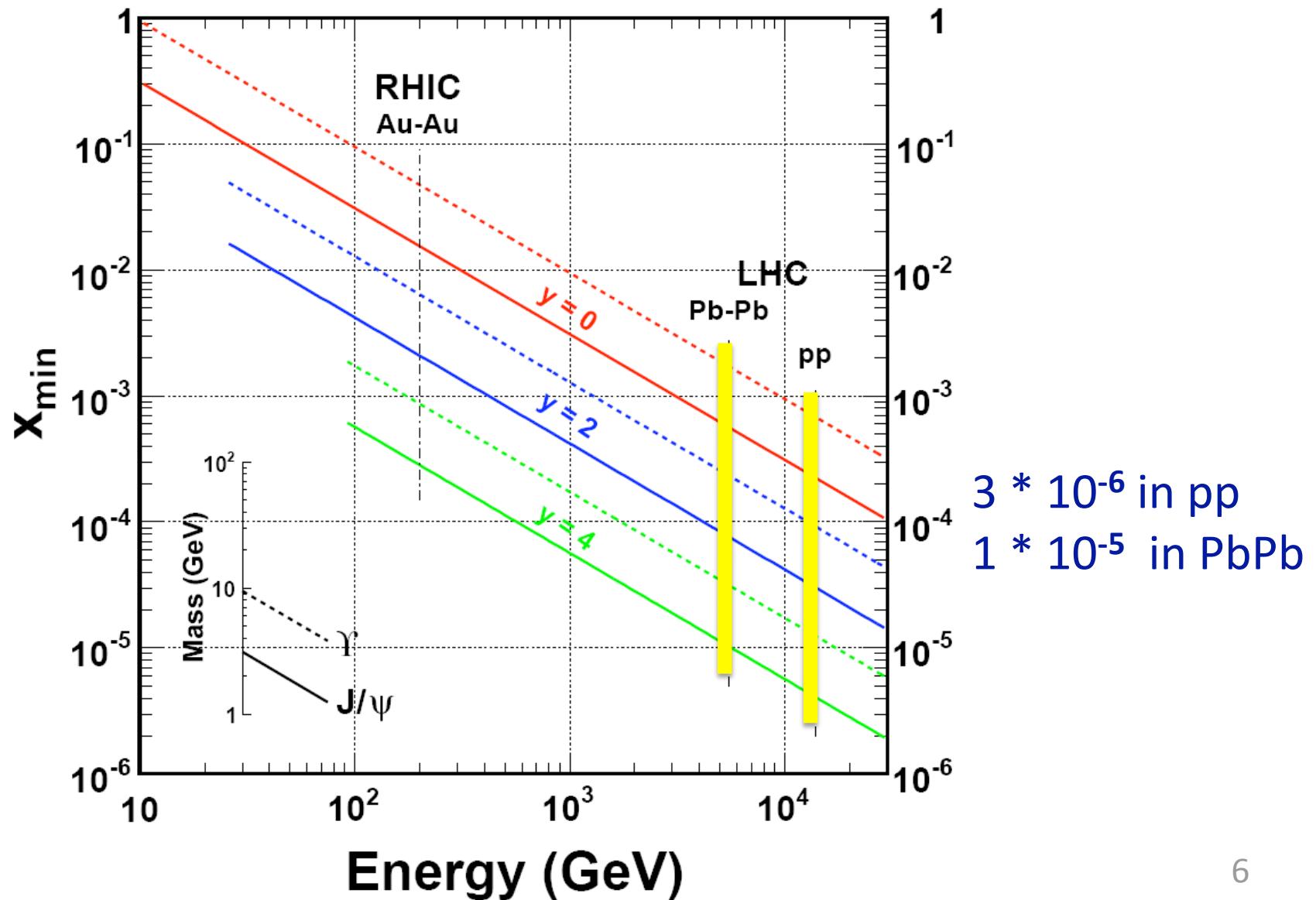
LARGE HADRON COLLIDER (LHC)

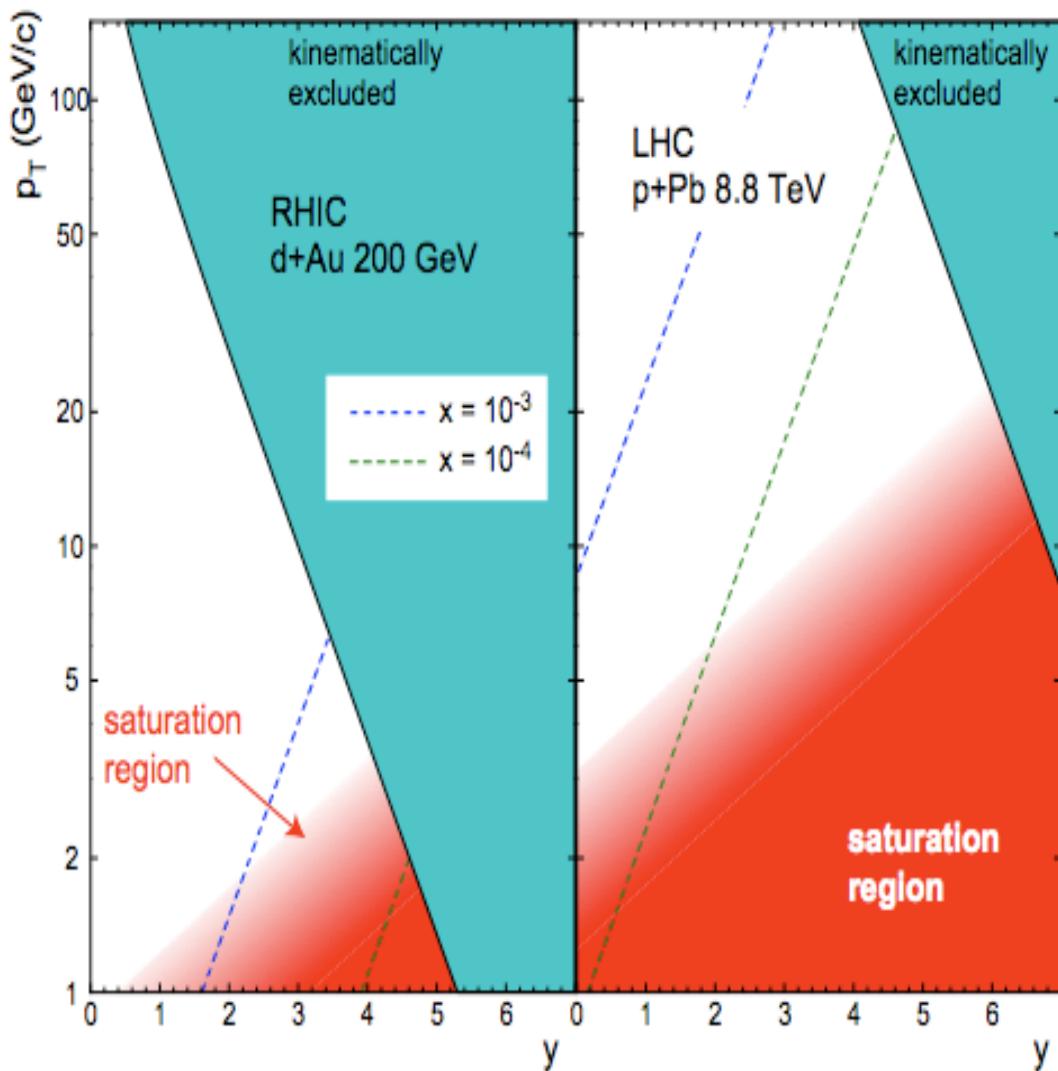
pp: $\sqrt{s} = 14$ TeV
pA: $\sqrt{s} = 8.8$ TeV
AA: $\sqrt{s_{NN}} = 5.5$ TeV



2009:
pp: $\sqrt{s} = 0.9$ and 2.3 TeV
2010:
pp: $\sqrt{s} = 7$ TeV
2010 Nov:
AA: $\sqrt{s_{NN}} = 2.75$ TeV
2011:
pp: $\sqrt{s} = 10$ TeV

LHC: Extending the low- x Reach

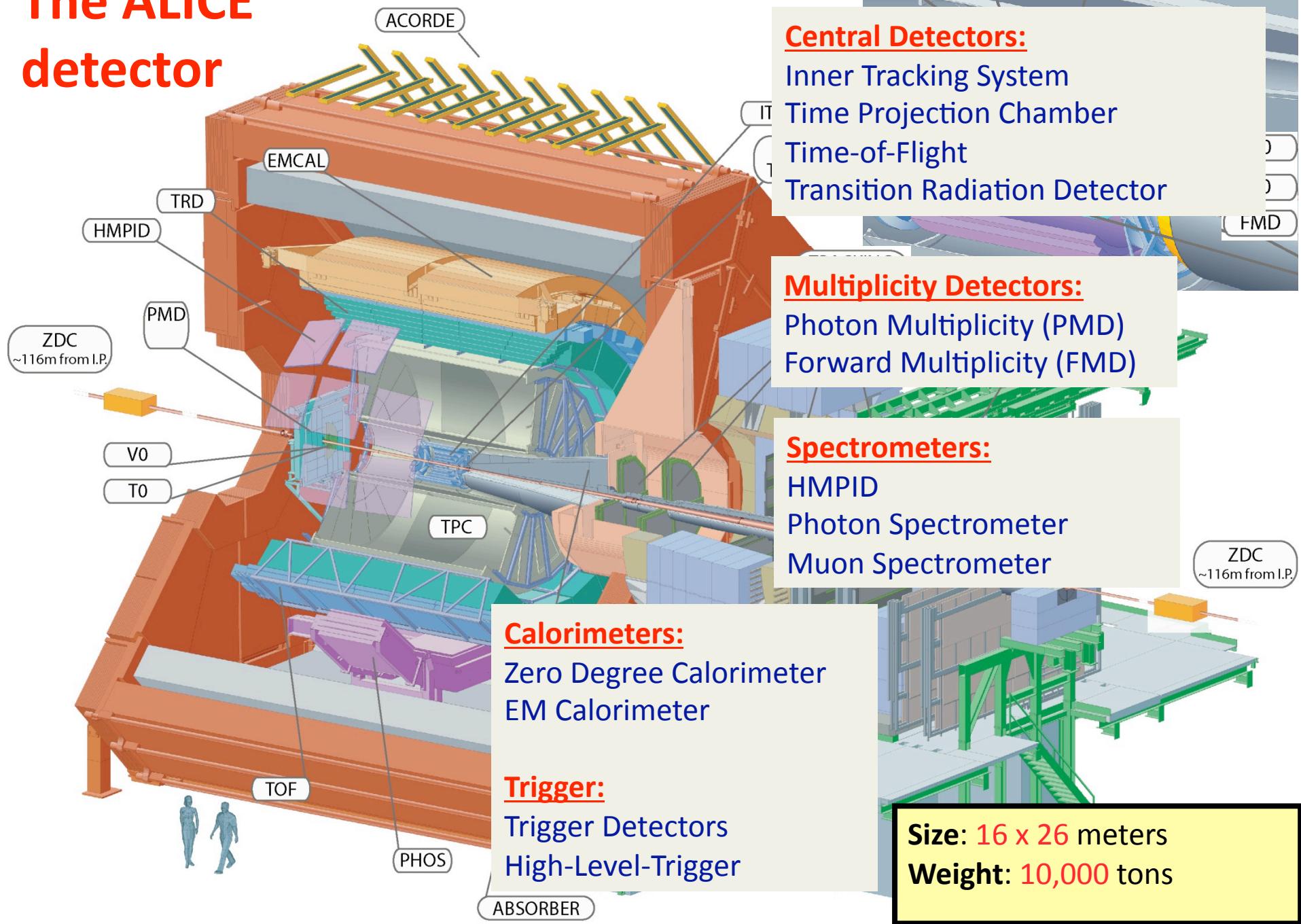




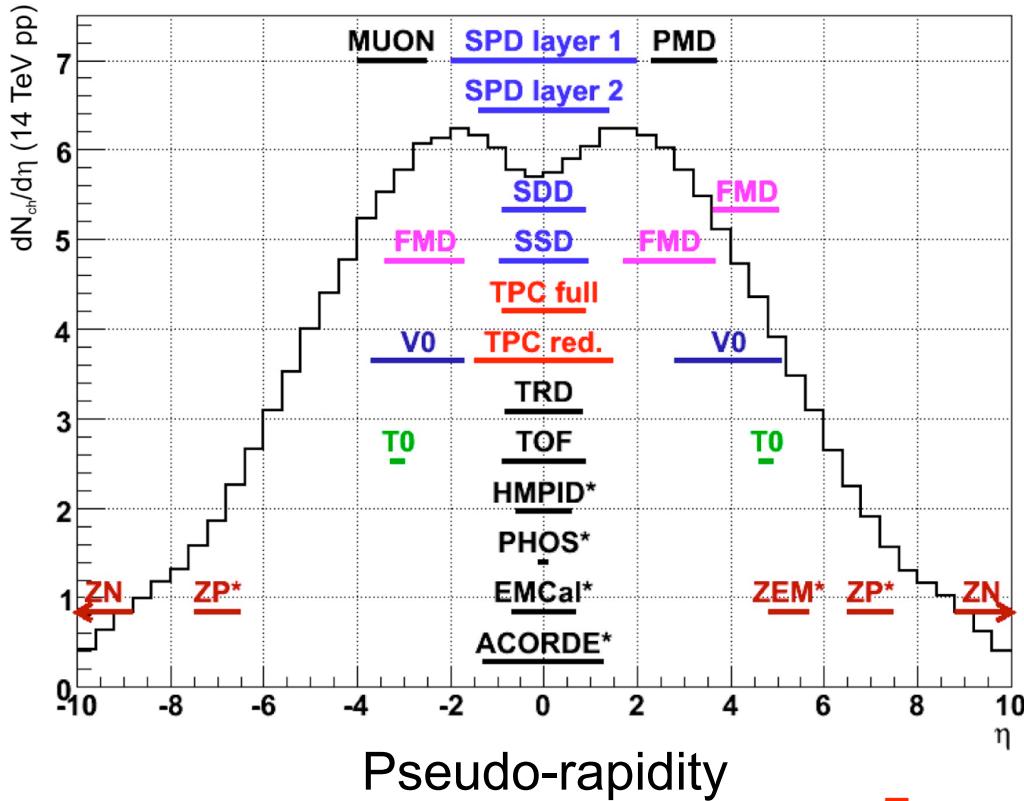
RHIC has opened the low- x frontier – indications for new physics (CGC)

LHC: Extends the low- x Reach by more than factor of 30 – gain in energy and larger rapidity extent

The ALICE detector



Unique features of ALICE



- Soft (down to 100MeV/c) to hard (>200GeV/c) physics
- **Low p_T cut-off (~100 MeV/c)**
- Excellent tracking and PID
- Excellent resolution on impact parameter
- Dedicated di-electrons and di-muons
- High resolution calorimeter for direct photons

Forward Detectors:

- Muon Arm: $-4.0 < \eta < -2.5$
- Charged particles: FMD ($-3.4 < \eta < 5.1$)
- Photons: PMD ($2.3 < \eta < 3.7$)
- V0, T0 trigger detectors
- ZDC



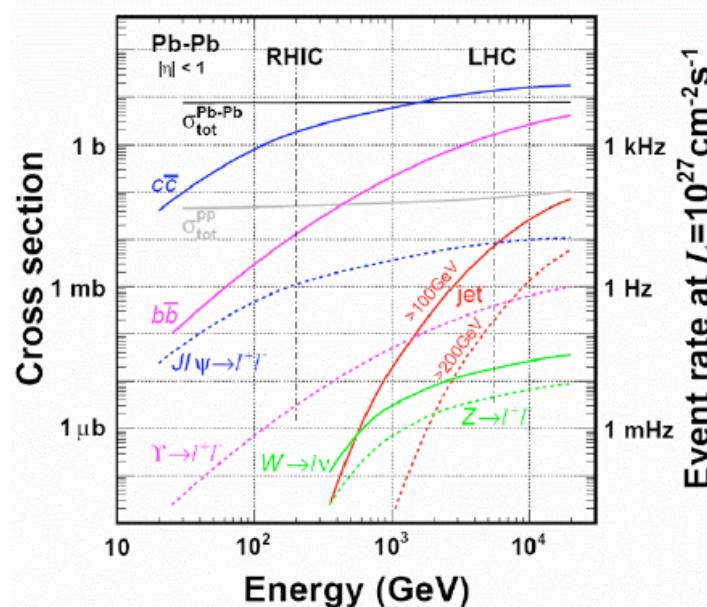
Probing small- x physics

Particle production at LHC is governed by high density parton distributions.

- Particle Multiplicities at forward and mid-rapidities
- R_{AA} , R_{CP} , R_{pPb} , Distributions of hadrons at mid-rapidity, forward rapidity, Suppression even at mid-rapidity (????)
- Long range rapidity correlations
- Heavy Flavour production – at mid and forward rapidity
- W production at the LHC – studied by the Muon Arm
- Lower beam energies @ LHC: possible to study the energy as well as Bjorken- x dependence of the global event features – can bridge the gap between top RHIC energy and LHC

Heavy Flavors in ALICE

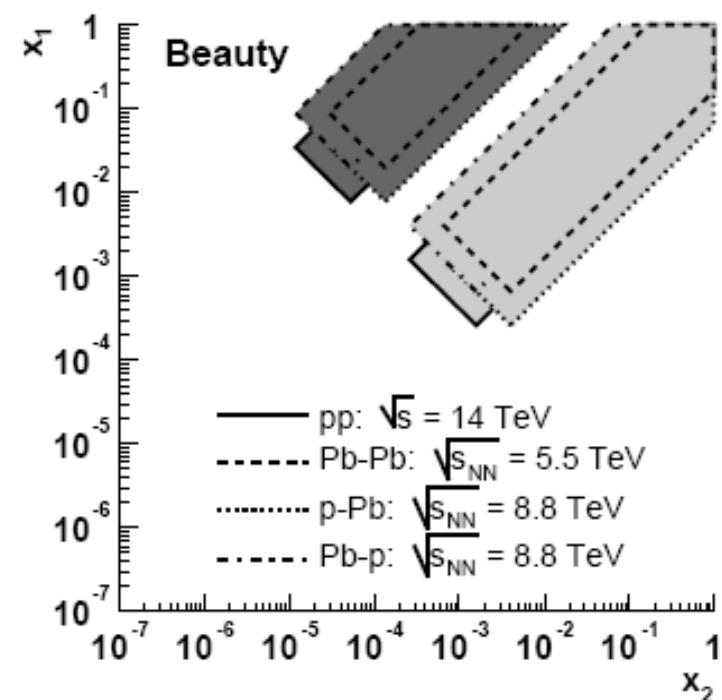
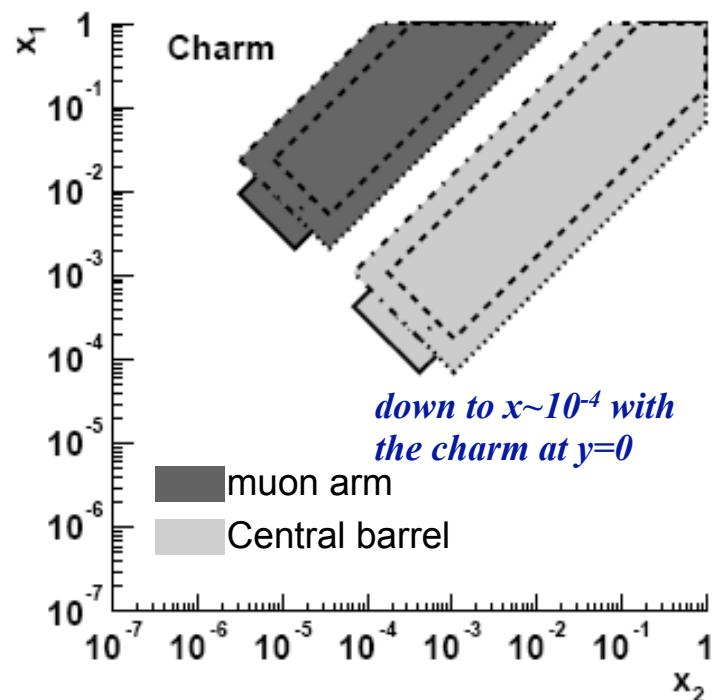
Large cross sections of charm and beauty:



- Channels:
 - electronic ($|\eta| < 0.9$)
 - muonic ($-4 < \eta < -2.5$)
 - hadronic ($|\eta| < 0.9$)
 - low- p_T region
 - central and forward rapidity regions
 - Both c and b
 - Precise vertexing in the central region to identify D ($c\tau \sim 100-300 \mu\text{m}$) and B ($c\tau \sim 500 \mu\text{m}$) decays

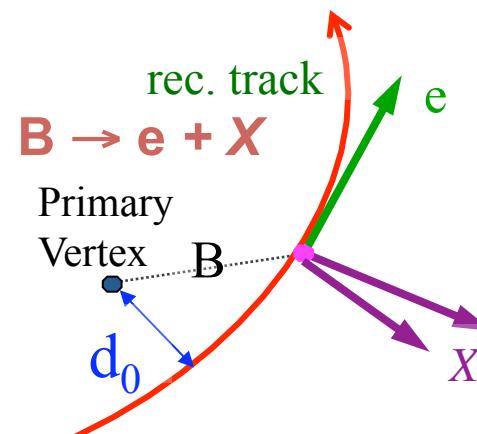
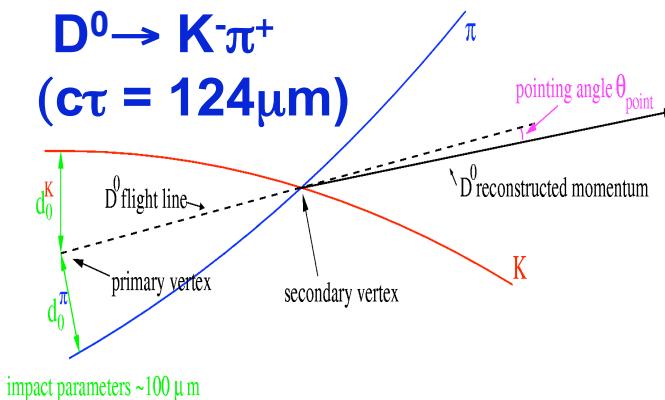
x -values for charm and beauty at $y=0$ and $p_T \rightarrow 0$

	SPS Pb-Pb 17 GeV	RHIC Au-Au 200 GeV	LHC Pb-Pb 5.5 TeV	LHC pp 14 TeV
c-cbar	$X = 10^{-1}$	$X = 10^{-2}$	$X = 4 \times 10^{-4}$	$X = 2 \times 10^{-4}$
b-bbar	-	-	$X = 2 \times 10^{-3}$	$X = 6 \times 10^{-4}$





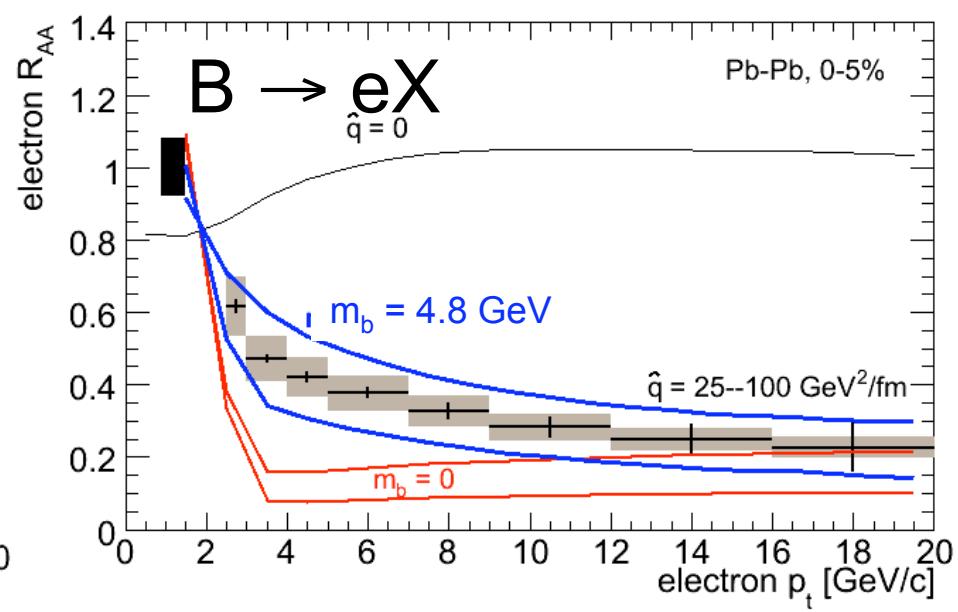
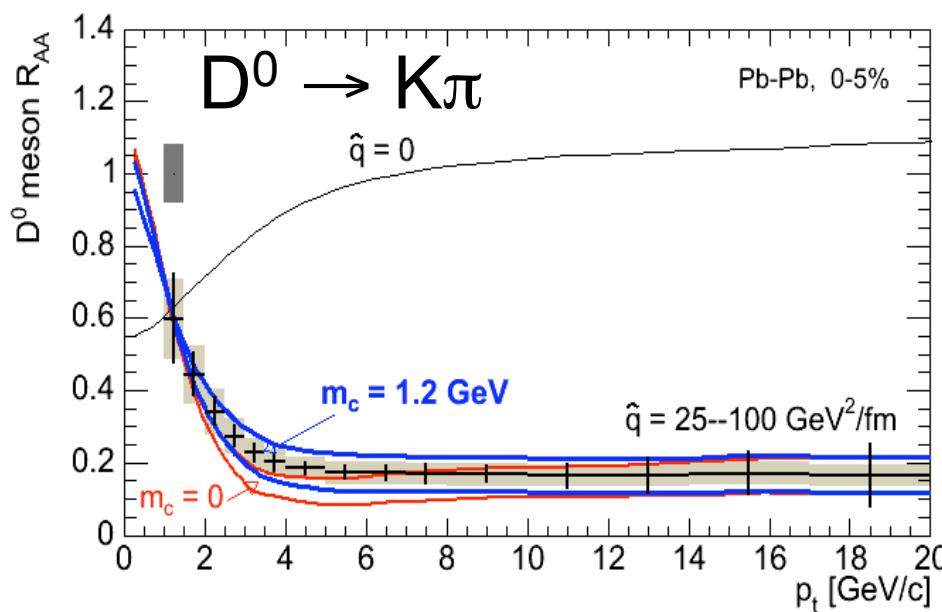
Observables: R_{AA}



$$R_{AA}(p_T) = \frac{1}{\langle N_{coll} \rangle} \frac{dN_{AA}}{dp_T} / \frac{dN_{pp}}{dp_T}$$

Francesco Prino

Low p_T : main effect on R_{AA} is nuclear shadowing
High p_T : main effect on R_{AA} is energy loss

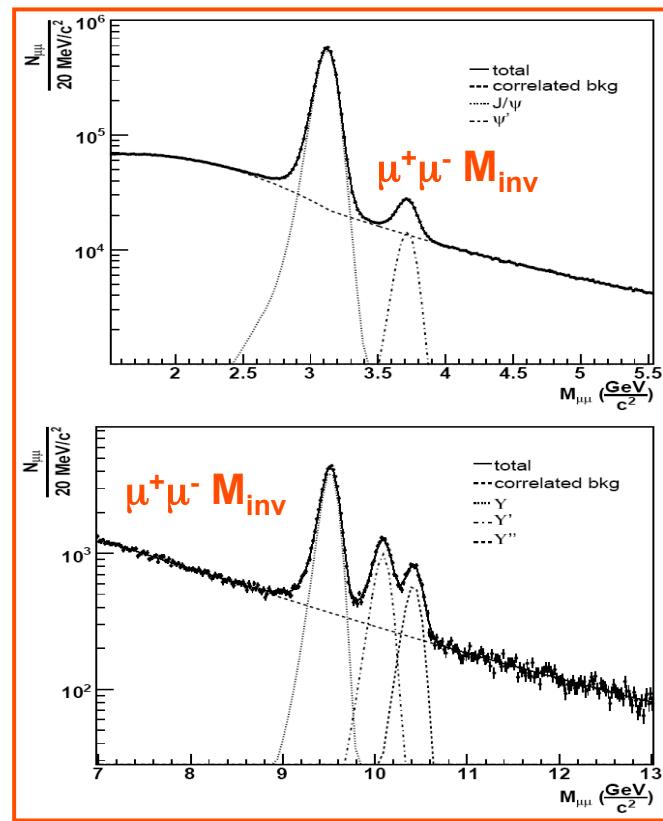
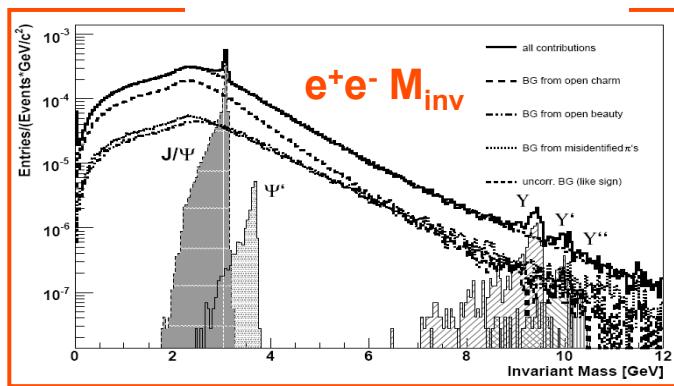


Energy loss from Armesto et al. Phys. Rev.D71 (2005) 054027.

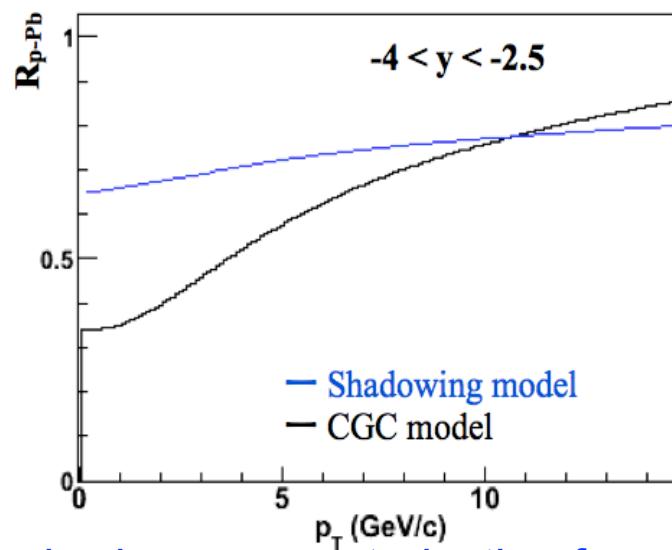
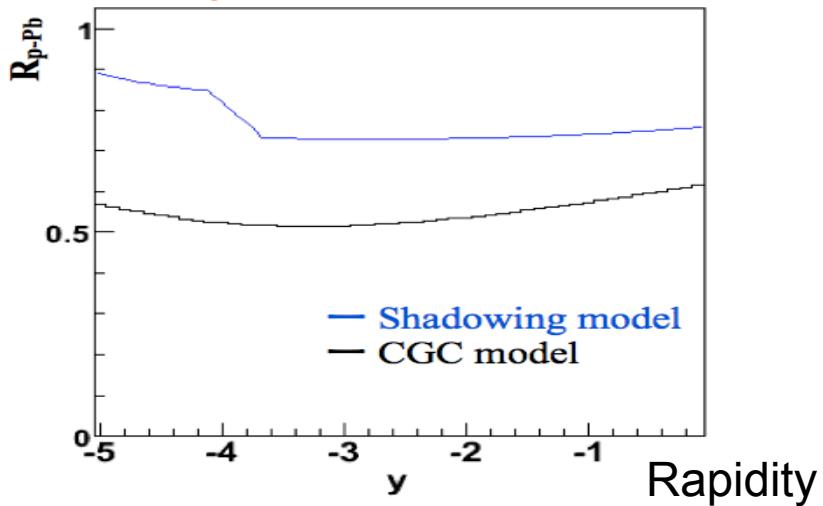


ALICE

Cynthia Hadjidakis

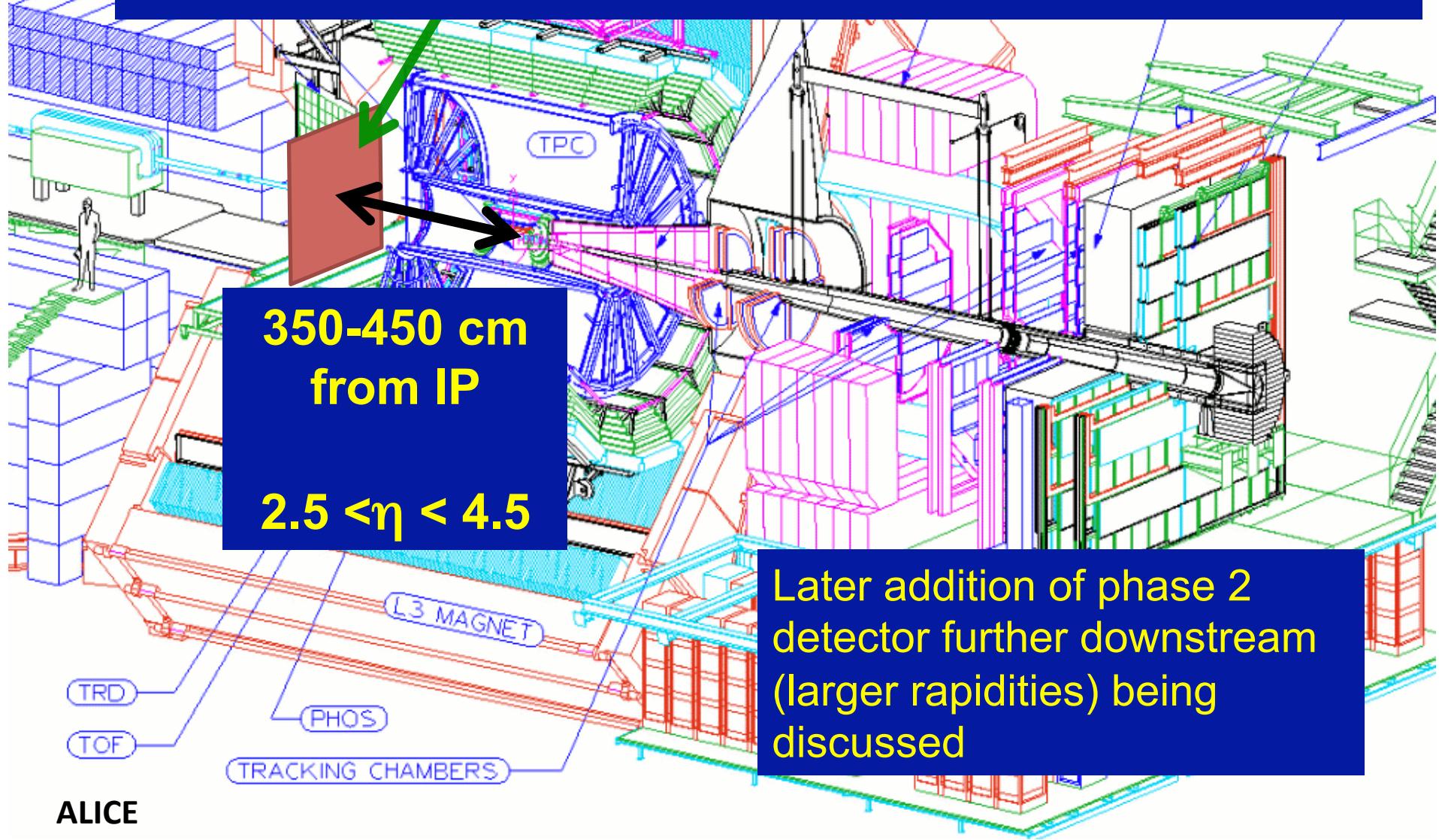


R_{p-Pb} for J/ ψ

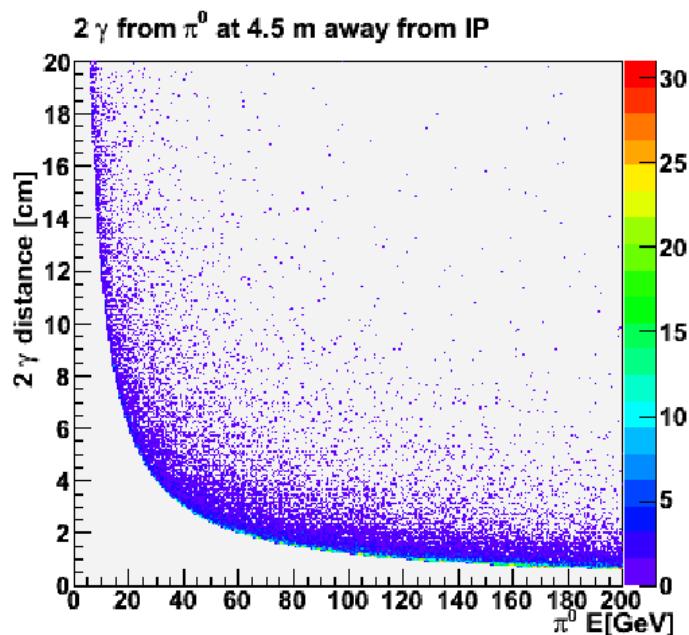
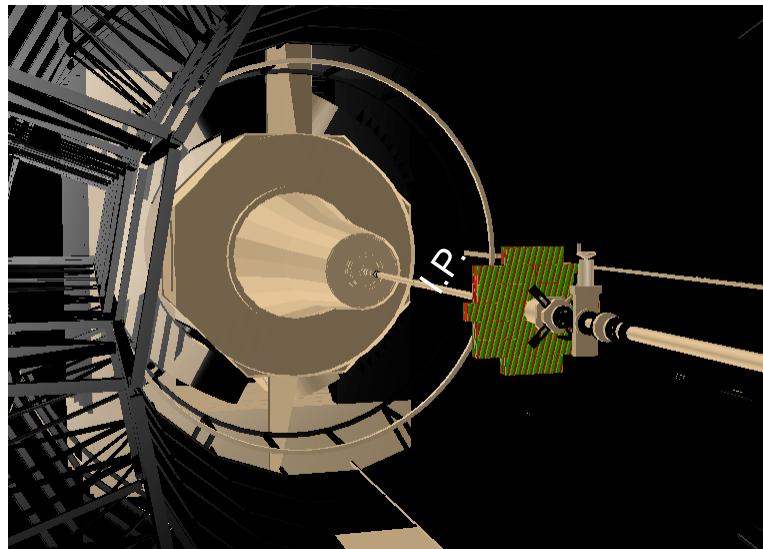


- Shadowing: parameterization from CDF data for p_T and energy dependence with EKS98
- Saturation: Fujii, Gelis, Venugopalan
Nucl.Phys.A780,2006

New Proposal: Forward EM Calorimeter in ALICE



Si - W Tracking Calorimeter



Capability for p-p, p-A and A-A collisions

- Pb-Pb collisions will define the granularity
- π^0 measurement up to 200 GeV/c momentum

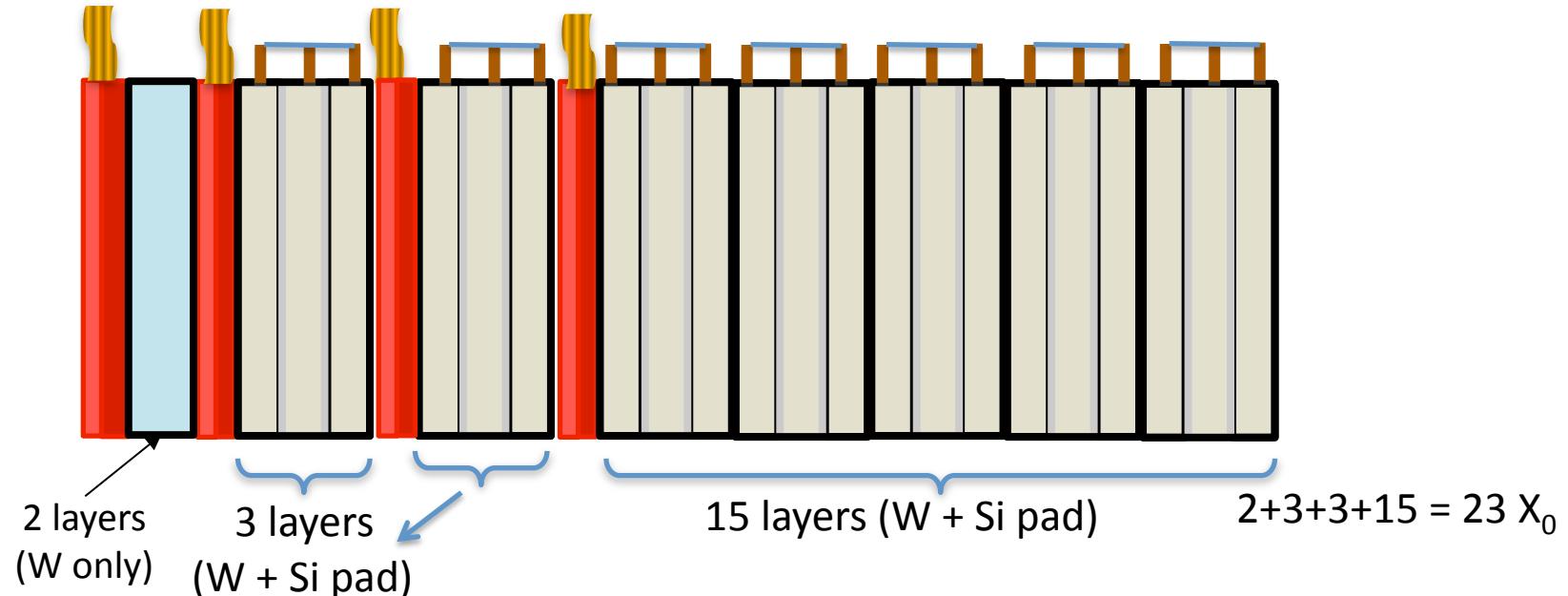
Requirements

- Small Moliere radius
- Capability of two photon separation at short distance less than 1 cm



Forward Calorimeter: Silicon – W Calorimetry

Particle →

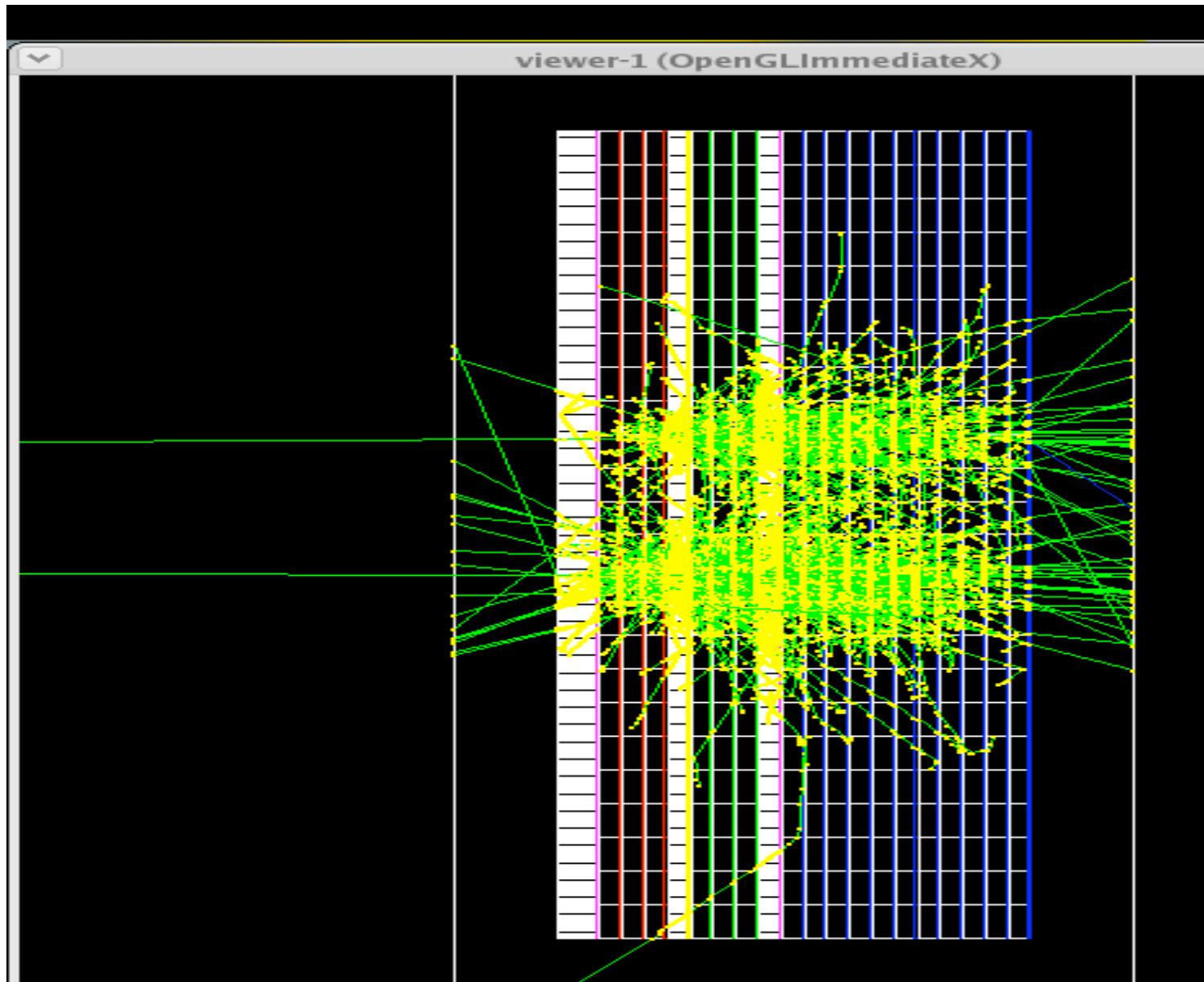


X-Y Si Strip
0.3 mm thickness
3 layers
Strip size 0.5 mm
Detector depth 5.5 mm

First Layer acts as Charged
particle VETO

Si Pad + W Si thickness Si size	0.3 mm 1 cm x 1cm
Only Tungsten (W) W thickness	3.5 mm
	About 20/sqrt(E) (%) resolution

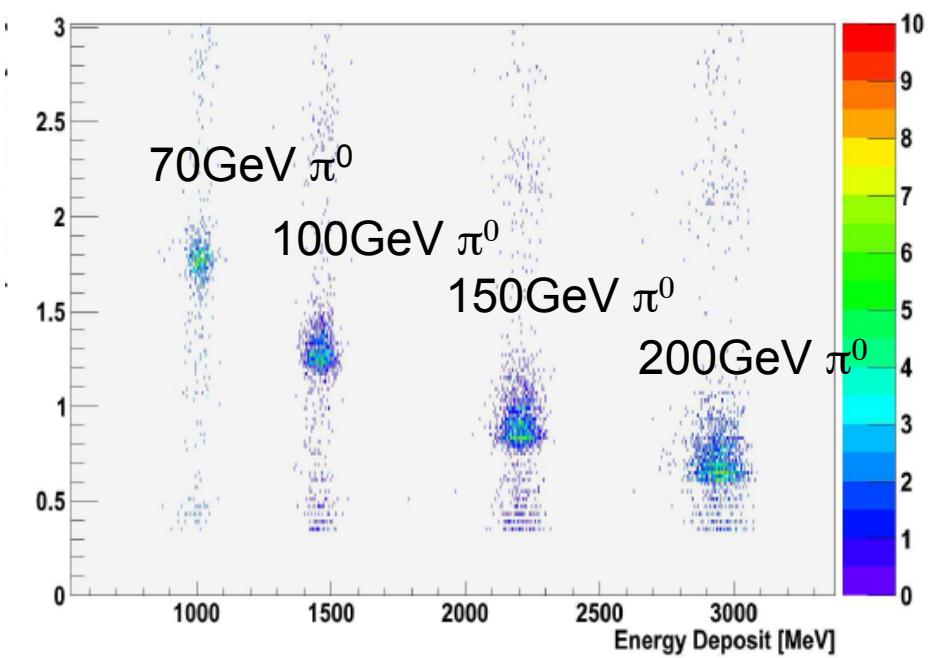
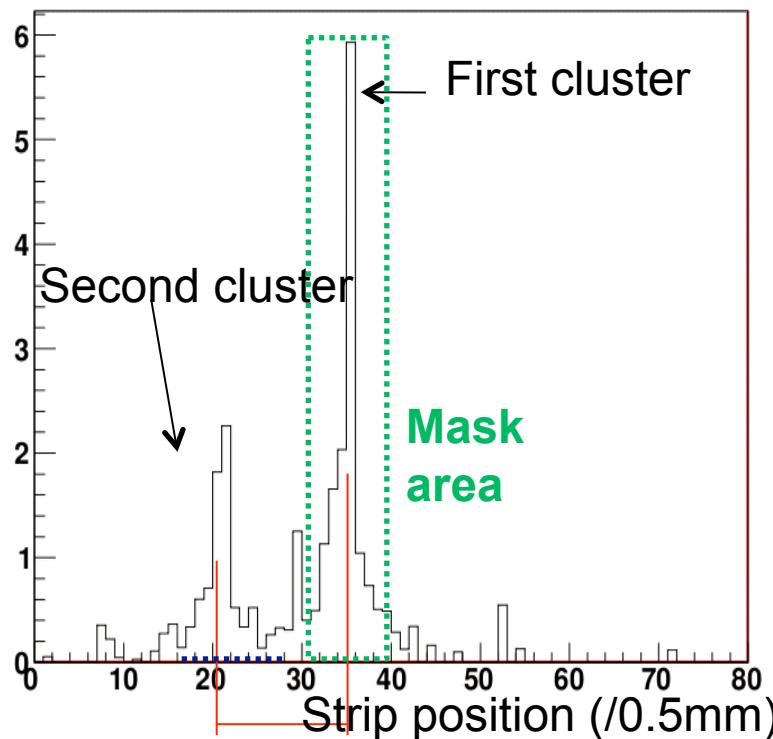
Geometry Implementation in Geant



- Detector at 350cm from IP
- 10 GeV/c π^0 decaying to 2γ
- Cluster Centers separated by ~4cm

π^0 reconstruction using Si-Strips

- Two clusters in the Si-pads start to merge into one cluster when the two-hit distance is below 2cm (for 1cm x 1cm pads)
- Locate a cluster with large energy deposit in the Si-pads & define search region in the Si-strips
- Search for two clusters & obtain distance between the clusters

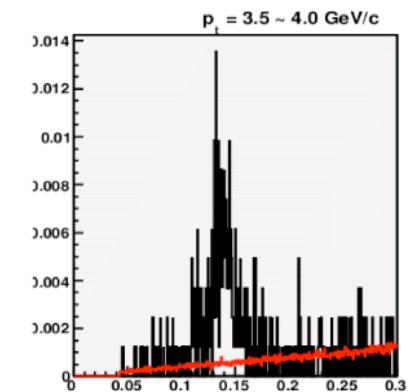
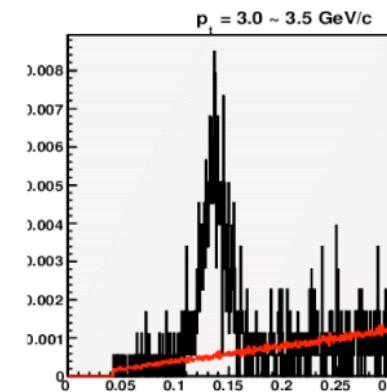
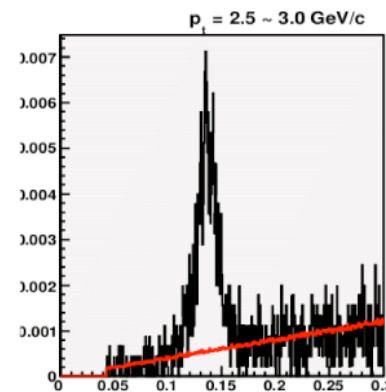
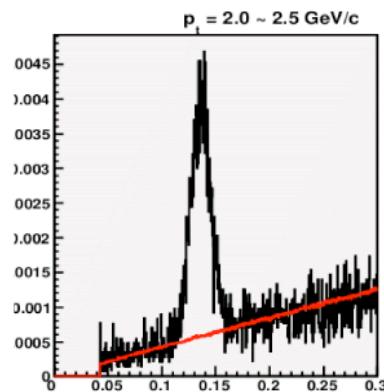
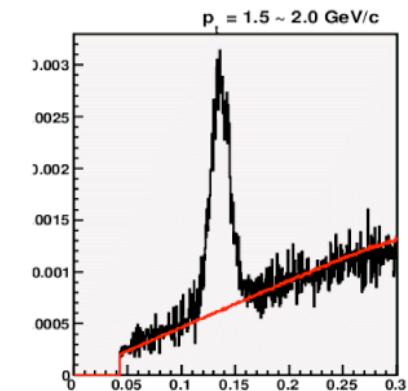
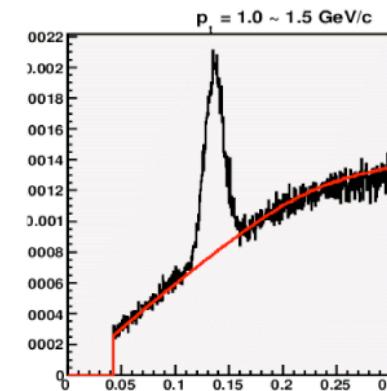
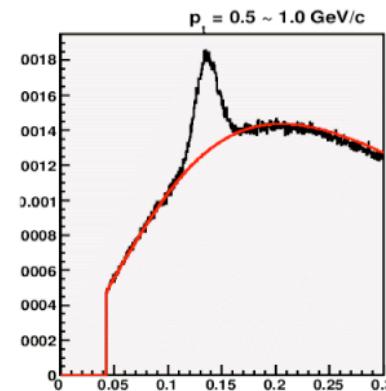
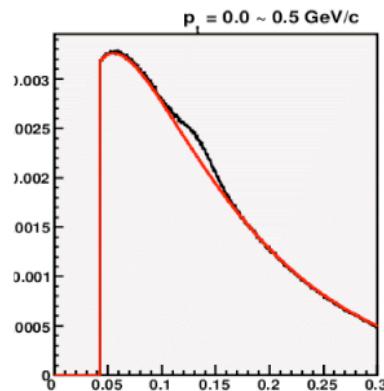




π^0 mass spectra in p-Pb at 8.8 TeV

Taku Gunji

$3 < \eta < 3.5$





Forward Calorimeter: Further study and status

Further Study:

- $\pi^0 - \pi^0$ correlations
- π^0/γ reconstruction
- γ – jet at forward rapidity
- direct photon detection at large rapidity
- reconstruction of other mesons decaying to γ or e^\pm :
 - $\eta \rightarrow \gamma\gamma$
 - $\omega \rightarrow \pi^0\gamma$
 - $K_{\text{short}} \rightarrow \pi^0\pi^0 \rightarrow 4\gamma$
 - $\eta' \rightarrow \gamma\gamma ?$
 - $J/\psi \rightarrow e^+e^- ?$

Status:

- Strong effort on simulation:
- Hardware efforts started
- Possible test beam in 2011
- Collaboration with PHENIX-FoCAL team

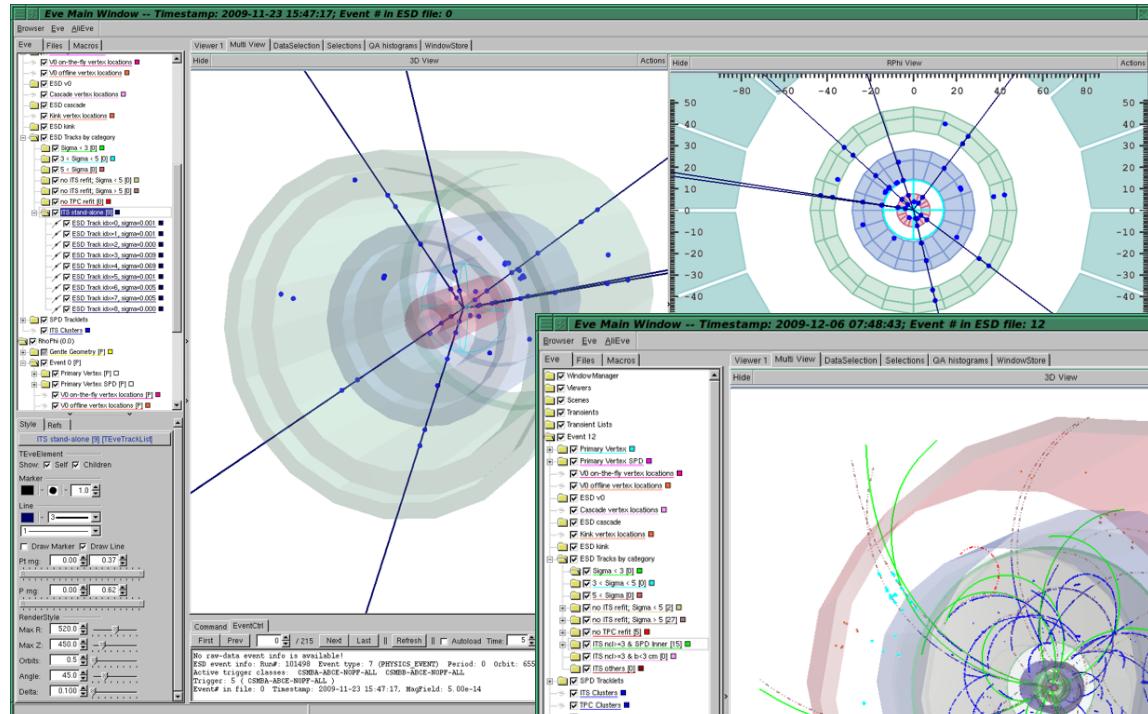
Time line:

Phase-I detector around 2013

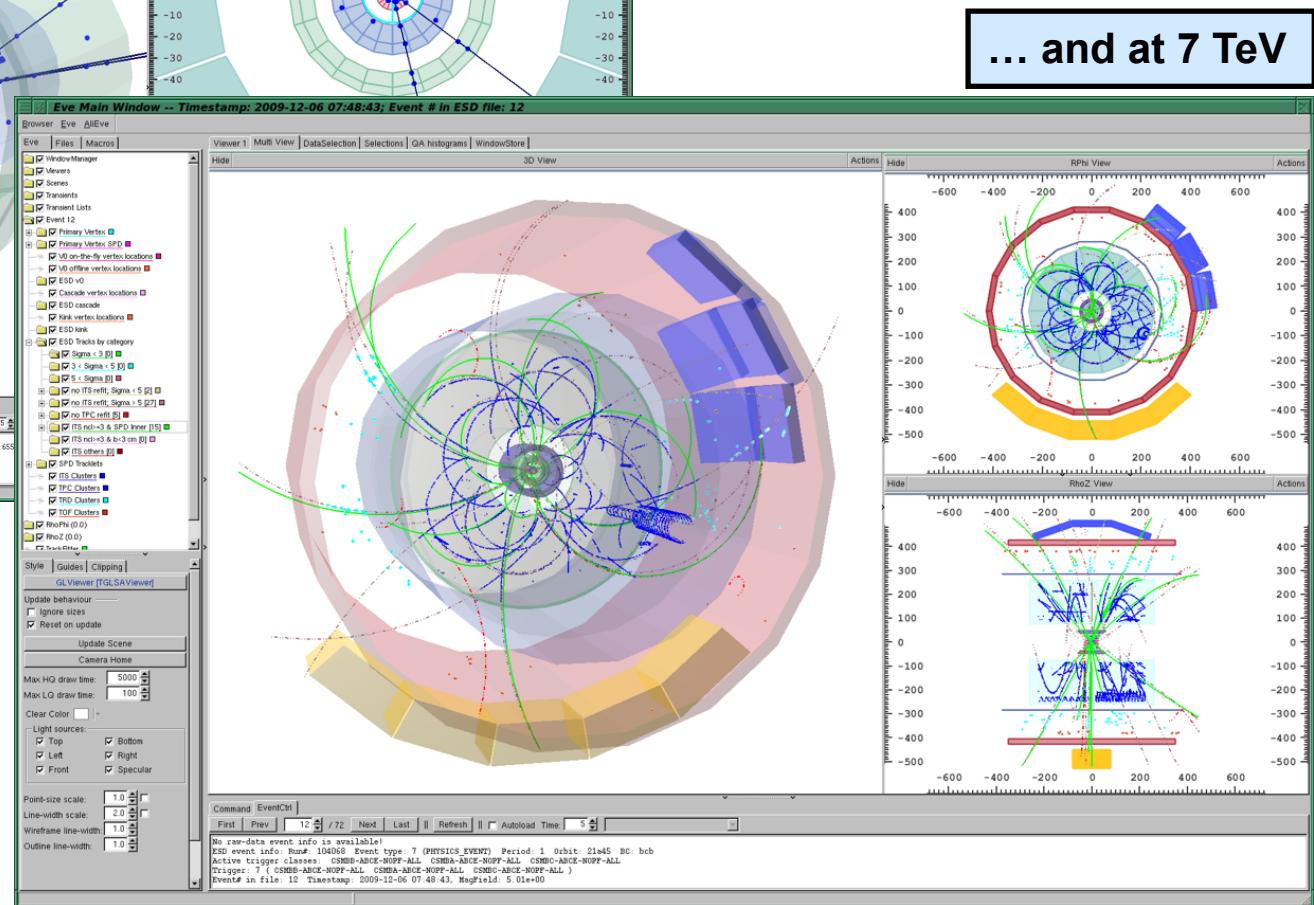


A Glimpse of First Physics Results

ALICE first event at 0.9 TeV ...



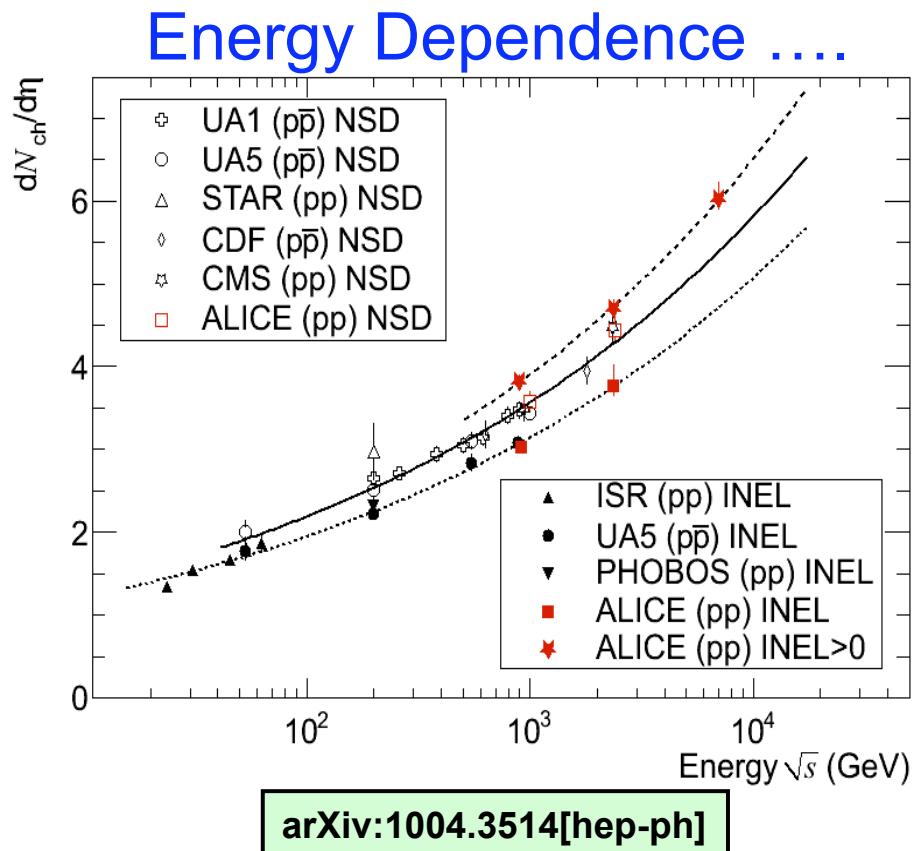
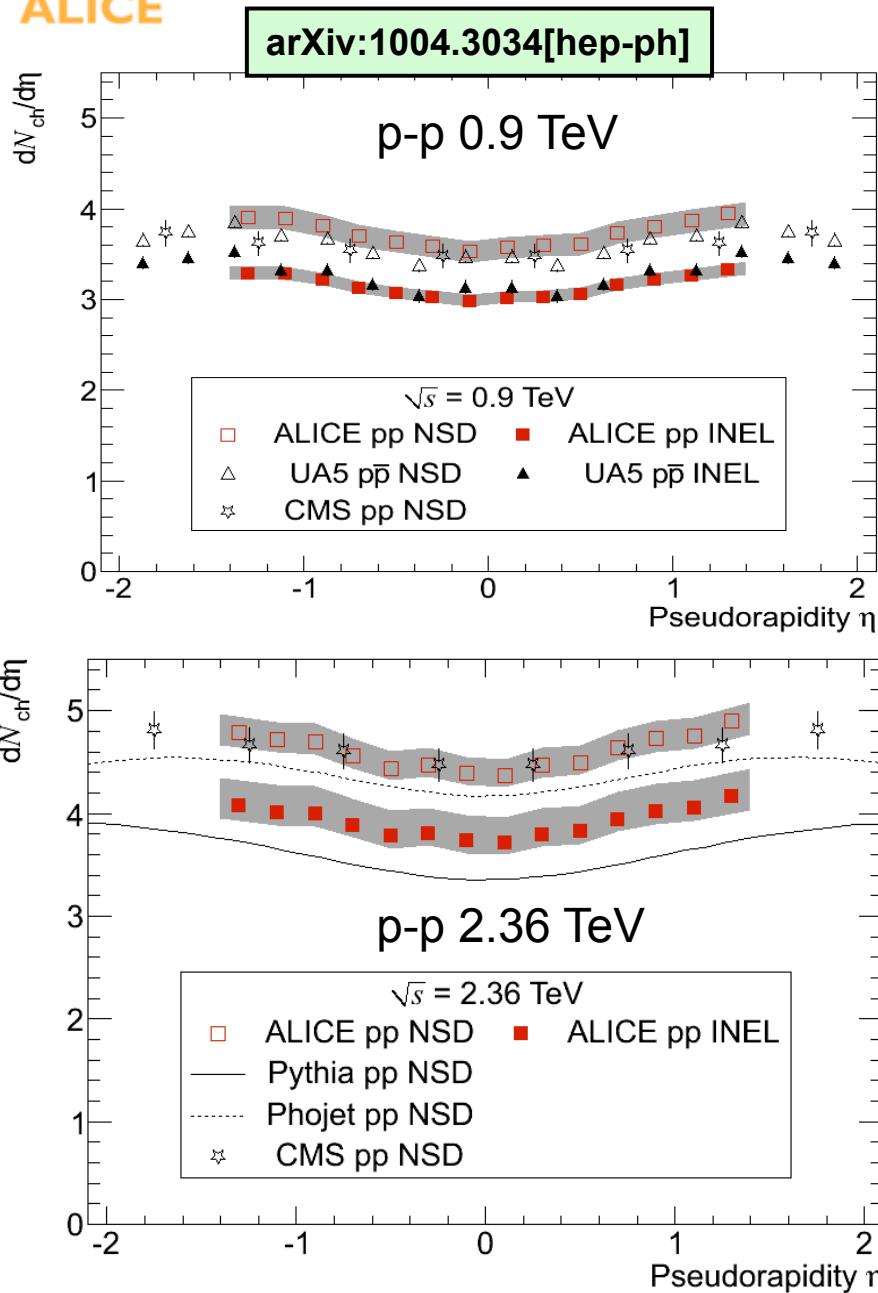
... and at 7 TeV



Excellent
Performance
of all detectors



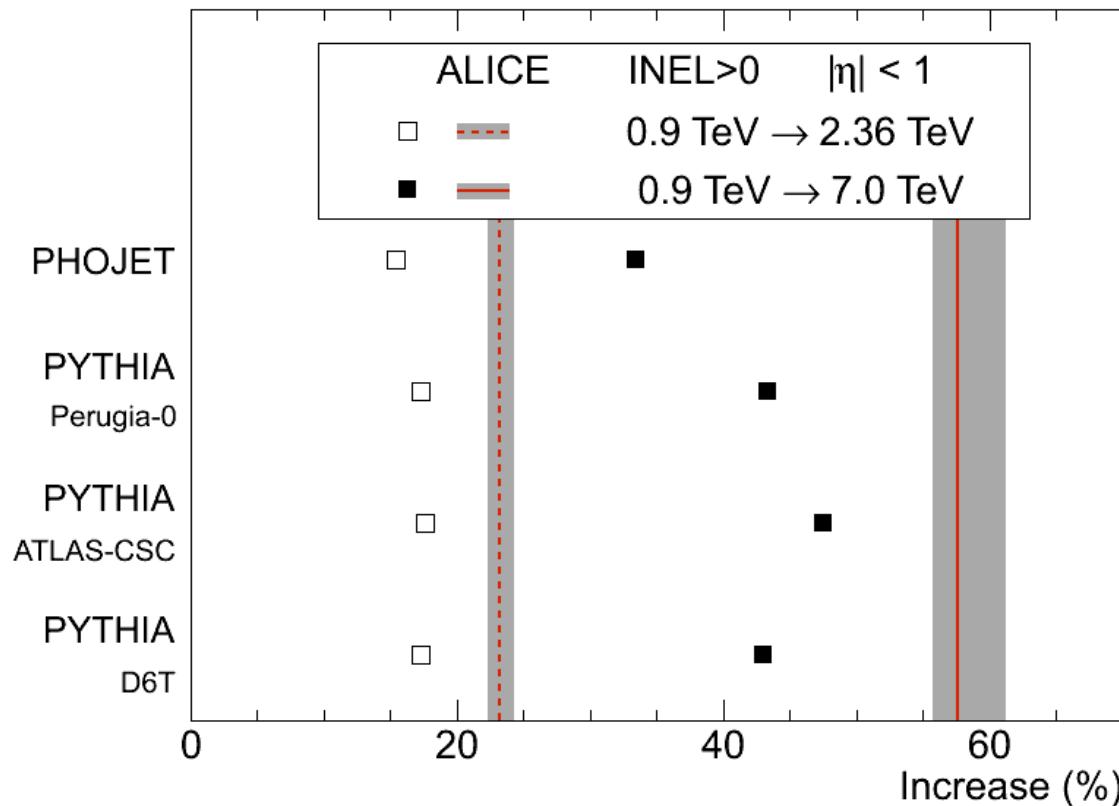
Charged Particles: $dN/d\eta$



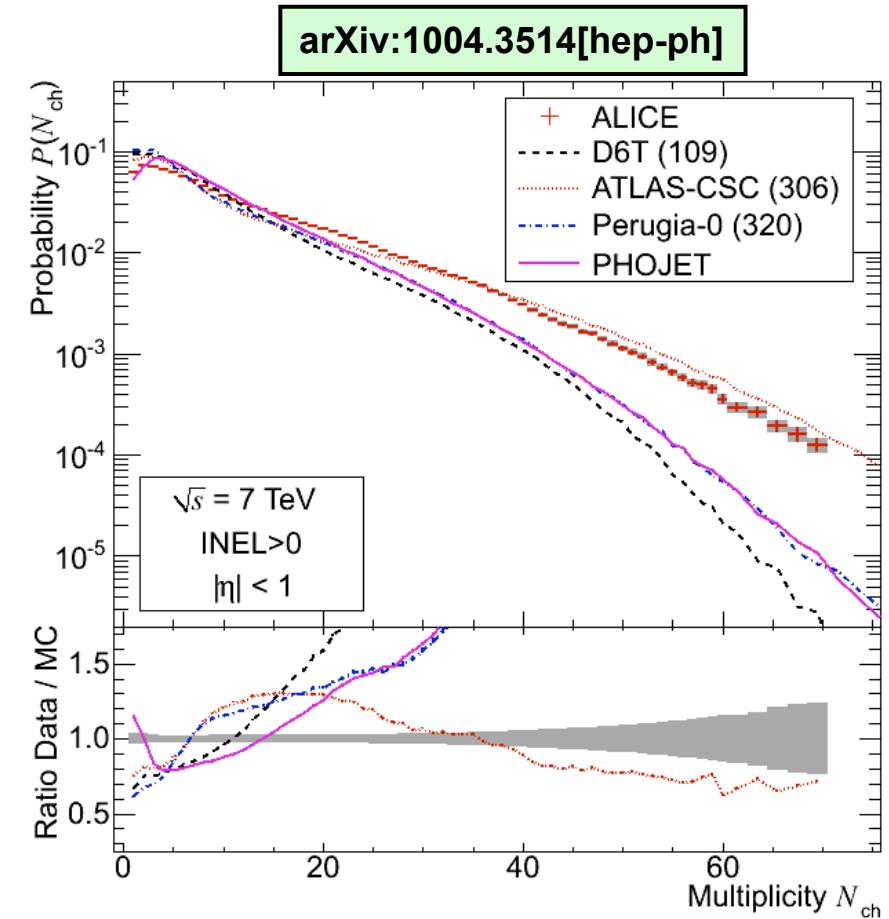
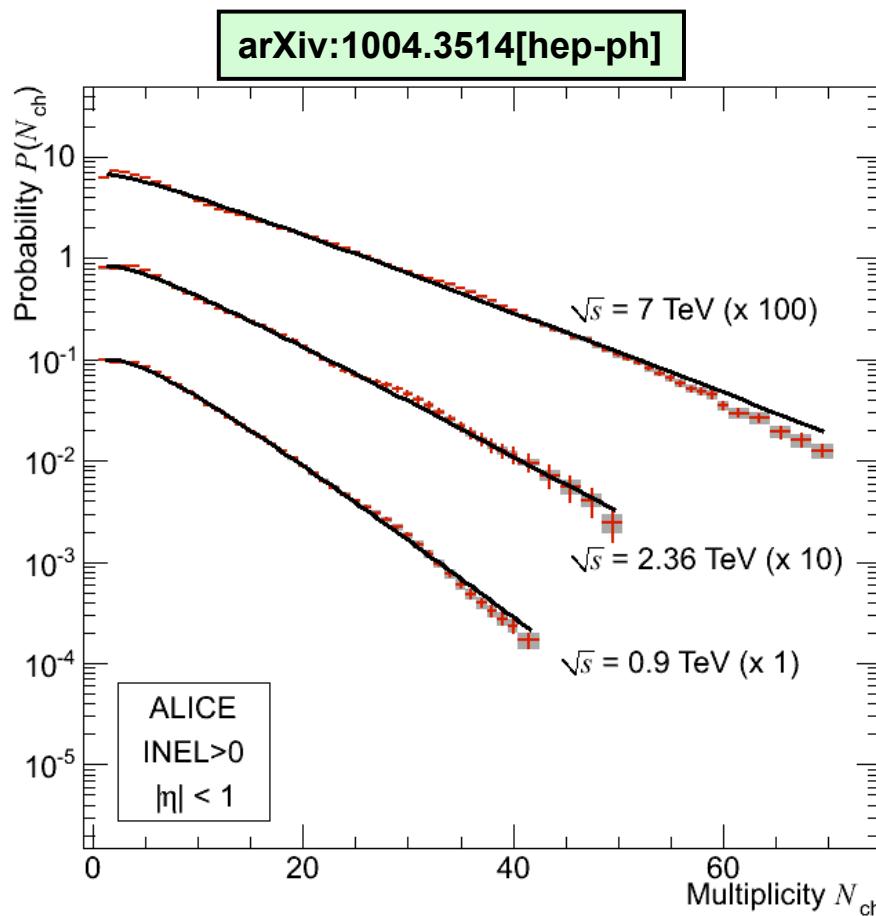
fit with power-law
dependence on energy

Charged Particles: $dN/d\eta$ comparisons

Increase from 0.9 TeV to 2.36 TeV and from 0.9 TeV to 7 TeV for ALICE compared to model predictions
 (Normalized to inelastic events ($\text{INEL}>0$) with at least 1 charged particle in $|\eta|<1$)

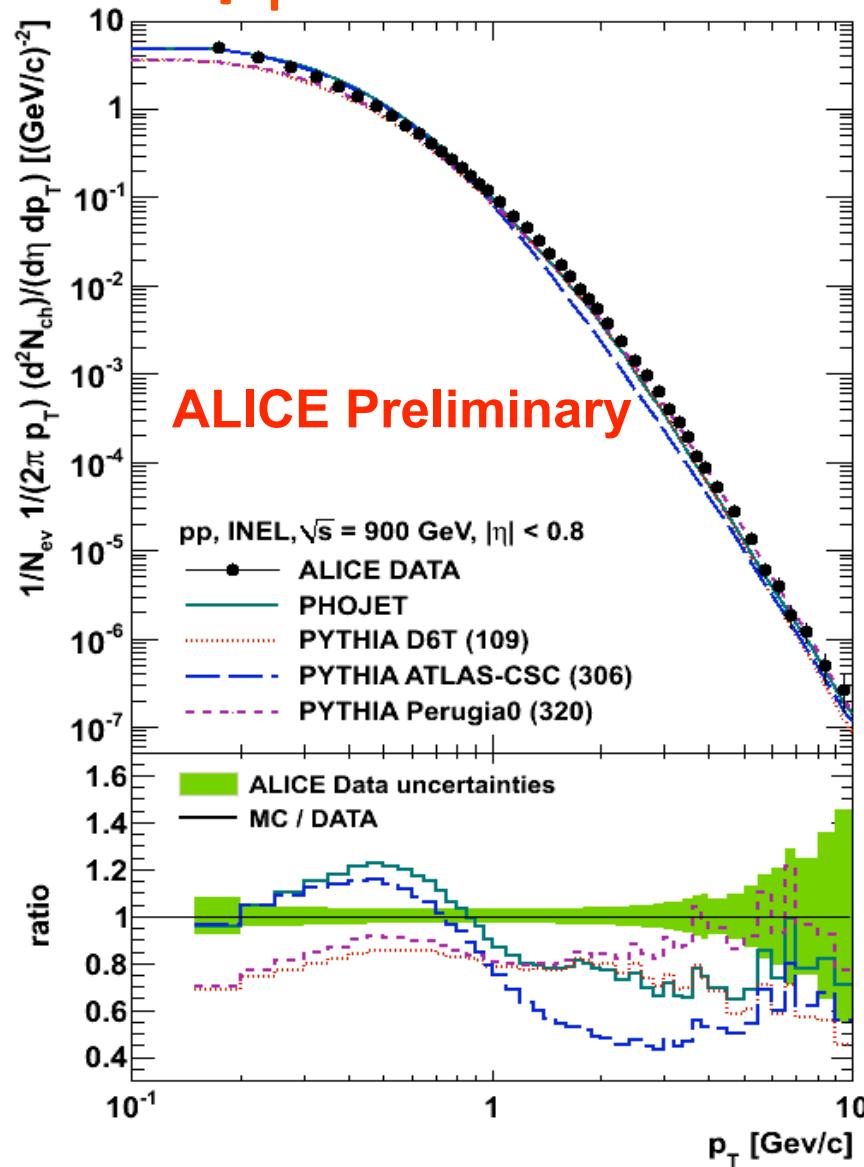


Charged Particles: Multiplicity Distributions

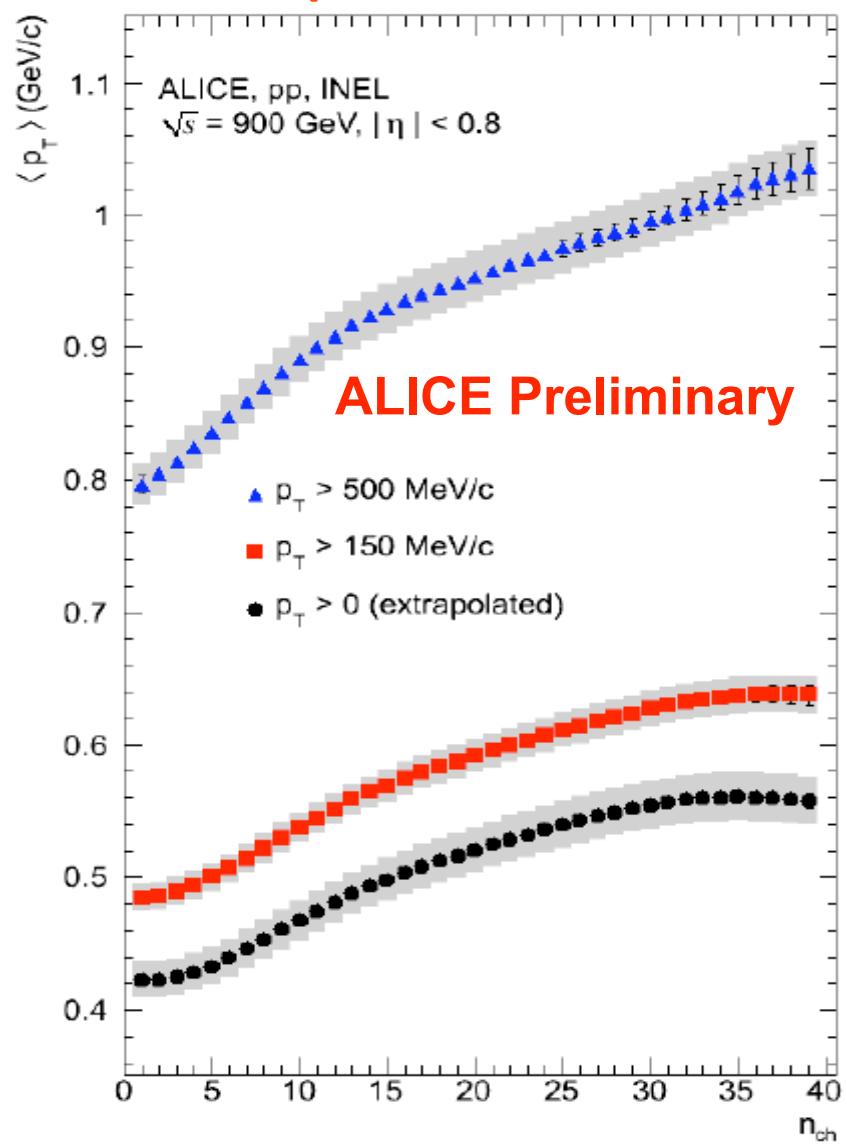


- Reasonably described by negative-binomial distributions
- Comparison with different models – not satisfactory

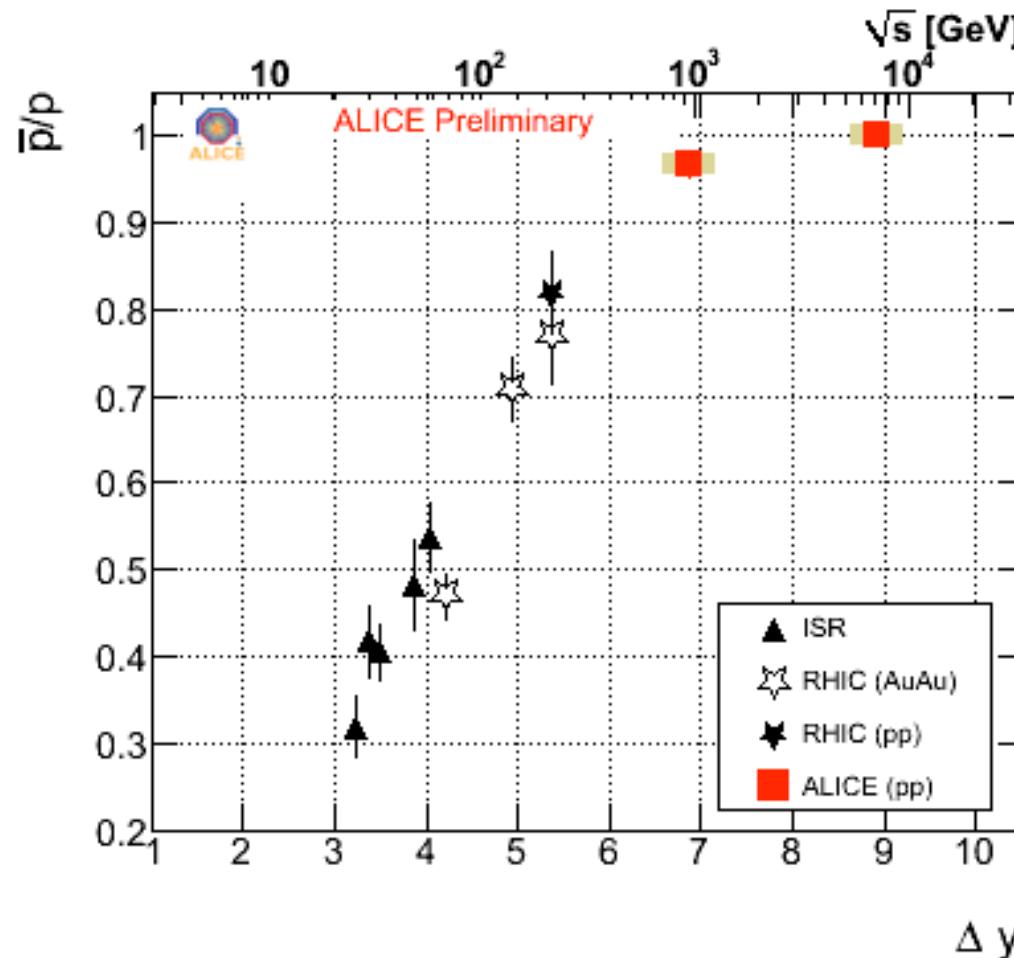
p_T Distribution



Mean p_T vs. Multiplicity



Pbar / p ratio


 Δy

- pp collisions:
- baryon transfer through large Δy
- value close to unity – little place for non-standard mechanism



Summary

- p-p, p-Pb and Pb-Pb collisions at LHC offer unprecedented opportunities for studying wide variety of physics related to small Bjorken-x
- Because of the low p_T acceptance of measured particles, ALICE is well suited for small-x study
- Most of the global observables measure by ALICE will be interesting from the small-x physics (CGC) point of view
Heavy flavours provide good tool for gluon saturation study
- Future instrumentation of Forward EM Calorimeter will be crucial to small-x physics of LHC